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ABSTRACT

This essay paper discusses the decline in the numbers of students studying mathematics at German universities. Sections on mathematics in German secondary schools, reasons for the decline in numbers, and issues related to reversing the trend are included. The article also highlights the German "Diplom" and mathematics departments in Baden-Wurttemberg. (MM)

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Declining Student Numbers Worry German Mathematics Departments

In the United States, shrinking student numbers in undergraduate mathematics programs have become commonplace. Figures from the AMS-IMS-MAA Annual Survey, showing that the number of juniors and seniors majoring in mathematics declined by about 20 percent between 1992 and 1998, will elicit little surprise. What is less well known in the U.S. is that similar declines are occurring elsewhere. One example is Germany, where the number of students choosing mathematics as a university subject has been dropping steadily for several years. Why these declines have occurred in Germany is not an easy question, but it is one that German mathematics departments have had to face as they try to come up with ways to reverse the trend.

The German *Diplom*

The organization of universities in Germany and the degree programs are quite different from what one finds at U.S. universities. Most universities in Germany are state universities which are open to all students and which charge no tuition. Students must choose a subject to study; the subject can be changed later on, but it is not possible, as it is in the U.S., to enroll as an "undeclared major". While some universities have recently established bachelor's and master's degrees, the typical first university degree in the sciences is the *Diplom*, which takes a minimum of four years and can take as many as six.

The first two years of study for *Diplom* students in mathematics consist of a fairly standard set of courses and end with an examination, called the *Vordiplom*, on the course material. After that, students have a great deal of freedom in what they study and how they arrange their coursework, though there are some requirements designed to ensure breadth in the mathematical topics they study. They also must choose a second subject of study; traditionally this was physics, but today it is often computer science or economics. In addition to taking lecture courses, mathematics students attend seminars, in which they lecture to each other about topics they are studying. To receive the *Diplom*, they must write a thesis, which is called the *Diplomarbeit* and is similar to a master's thesis in the U.S., and they must pass a set of oral exams called the *Diplomprüfung*.

In addition to the regular mathematics *Diplom*, many German mathematics departments offer a *Diplom* in such subjects as *Finanzmathematik* (financial mathematics), *Versicherungsmathematik* (actuarial mathematics), and *Wirtschaftsmathematik* (applications of mathematics to economics and/or managerial science), and various combinations of these topics; there are also programs in *Technomathematik* (engineering mathematics). Mathematics departments also educate *Lehramt* students, those intending to teach mathematics in secondary schools.

Data about the numbers of students in a particular subject in Germany usually focus on the numbers of beginning students choosing that subject. This method of counting can be imprecise, because many students later drop out or switch to another subject. Because there are no restrictions on the number of students enrolled to study mathematics, student turnover can be quite high. Nevertheless, trends in the numbers of beginners year to year do give an indication of student interest in a subject.

Figures from the Statistisches Bundesamt, the central clearing house in Germany for national statistics, show a drop of around 20 percent in the number of beginning students in mathematics between 1992 and 1999; for students choosing mathematics in their first semester of university studies, the drop is about 35 percent. Interviews with faculty in mathematics departments around Germany reveal that in many places the numbers have declined further. For example, at Universität Münster, one of Germany's largest universities, the number of beginning *Diplom* students in mathematics dropped about 35 percent, from nearly 300 in 1990 to around 185 in 1998. Smaller departments have not fared much better: Universität Konstanz had 35 beginning students ten years ago and now has just 10; Universität Regensburg saw its beginners decline by about three-quarters in the same period. At Göttingen, which has perhaps the most illustrious history of any mathematics department in Germany, student numbers have fallen from around 80 ten years ago to a little more than

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40 today. And in the mathematics department at Bonn, generally considered to be the country's leader in terms of research, beginning student numbers dropped by more than half in just the past four years. For the first time the Bonn department is having trouble finding enough participants for seminars for students in the first year after the *Vordiplom*.

The declines in student numbers have created great pressures on mathematics departments. The state ministries overseeing the universities, needing to cut costs, have begun to look closely at departments where student numbers are declining and to ask hard questions about whether so many professors are needed if the students are not coming. As a result, many mathematics departments are finding it harder to get their administrations to agree to refill positions that become vacant through retirements or resignations. Sometimes the positions are transferred to another department where student numbers are higher, and sometimes the administration insists that the hiring be done in a certain area, often one with ties to an area of application such as computer science.

Mathematics departments in the U.S. also encounter these kinds of problems, but in Germany there is a special twist. Most German universities have a method of assessing the teaching capacity of the faculty; one such is the *Kurrikularnormwert*, which was developed after university enrollments swelled in the 1960s. The universities needed a way to calculate, given the number of faculty, how many students they could accept and when to impose admissions restrictions in certain subjects. Today the *Kurrikularnormwert* is being used in the opposite way, to estimate how many faculty positions are needed, given the number of students enrolled. Under this assessment method, many departments, including mathematics departments, are found to be overstaffed.

What is more, many in German mathematics departments believe that these measures do not provide a fair assessment of their service teaching load. The amount of teaching credit points a department receives for a given student usually depends on that student's subject: For example, a computer science student typically provides more teaching credit points than does a mathematics student. Compounding this problem is a phenomenon that is common in the U.S. as well: mathematics service courses being taught by faculty outside the mathematics department.

Why Are the Numbers Declining?

Asked why the declines in numbers of *Diplom* students have occurred, German mathematicians do not seem to have any easy or obvious answers. One could imagine a demographic explanation: Germany is now experiencing a local minimum in the number of college-age people. However, the proportion going to university has risen. As a result, according to figures from the Statistisches Bundesamt, the number of students attending German universities has declined only about 2 percent since 1992; in fact, in some smaller German states in the eastern part of the country the numbers attending university are up dramatically.

What about job prospects for those receiving the *Diplom* in mathematics? The job market for those in technical subjects did worsen after the reunification of Germany in 1989, though even then mathematics *Diplom* students tended to do fairly well compared with students in other subjects. Today mathematics faculty across the country seem generally to concur with Friedrich Götze of Universität Bielefeld, who calls the opportunities for mathematics students "splendid". "Companies like mathematicians because they are flexible, they are bright people—and they don't give up!" he remarked. Such students are quickly snapped up by banks, insurance companies, and software houses and often receive offers even before completing their degrees. One problem may be that secondary school students considering what subject to choose in university simply do not know that mathematics *Diplom* students have such bright prospects.

In trying to understand the decline in student interest in mathematics in Germany, it is important to note that there have also been comparable declines across the hard sciences, particularly in physics and chemistry. The subjects in which student numbers have been rising include law, business administration, and economics. Biology is also popular: There are admission restrictions for this field, and there are always more students applying than can be admitted. Enrollments in computer science have soared; the number of beginning students rose more than 50 percent between 1992 and 1999. Computer science may be absorbing many students who have interest in and aptitude for studying mathematics. "Mathematics has to try hard to attract these students back," said Karl-Heinz Hoffmann, immediate past president of the German Mathematical Society and head of caesar (center of advanced european studies and research), a research institute founded in 1995 in Bonn.

Views on the decline in student interest in mathematics seem to converge on two explanations. First, mathematics—and indeed the hard sciences generally—is difficult, and today's students are not seeking deep intellectual challenges. "I don't want to say that German students are lazy," said Hoffmann. "But they are looking for an easier way to get a degree" than studying mathematics. Hermann Karcher of Universität Bonn echoes this view: "Mathematics has the reputation of being a tough field to study, and we don't get the message across that it's a lot of fun." Computer science is not an especially easy subject either, but there the image of the hacker turned

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Tough Times in Baden-Württemberg

The mathematics departments in the German state of Baden-Württemberg have seen tough times in recent years. The state went through a cost-cutting exercise that mandated deep reductions in mathematics faculty across the state. Two mathematics departments were especially hard hit and barely escaped being closed down altogether.

How did this come about? The state of Baden-Württemberg, home to some of the most important universities in Germany, has nine altogether: Freiburg, Heidelberg, Hohenheim, Karlsruhe, Konstanz, Mannheim, Stuttgart, Tübingen, and Ulm. Pressed by financial difficulties, the state ministry overseeing the universities appointed a "structure commission" in 1996 to provide recommendations for where to cut. The commission consisted mostly of people from industry, university administration, state government, and philanthropic foundations; there was representation in biology and economics, but not in mathematics.

The commission relied on information and data provided by the ministry and did not visit or consult directly with the universities involved, much less individual departments. As a result, the commission labored under some misperceptions. For example, one of the reasons it gave for cutting mathematics departments was that *Diplom* students in mathematics faced poor job prospects. This was "really ridiculous," said Rainer Weissauer of the mathematics department at the University of Mannheim. Weissauer explained that the commission relied on information from the five years after the 1989 reunification in Germany, when there was a general saturation of the job market as workers from the eastern states moved westward. Even then, mathematics *Diplom* students fared better than those in other subjects, but today, as any German mathematics department can attest, there have been for several years now excellent job opportunities for those receiving the *Diplom* in mathematics.

Among the commission's recommendations, presented to the ministry in 1998, was that the number of mathematics faculty across the state be cut by 25 percent. The commission also said that two mathematics departments, in Konstanz and Mannheim, should be closed down; this would mean that the faculty would be reduced by attrition to a small corps for service teaching. In some sense these two departments were natural targets for cuts, because they are the smallest mathematics departments in Baden-Württemberg. In addition, the University of Mannheim is primarily a business school and has no natural sciences apart from mathematics. In the commission's recommendations, mathematics was not singled out for cuts; indeed, reductions were called for in nearly every subject. Only a few areas, such as computer science and business administration, were de facto spared.

The universities, feeling that the recommendations had been imposed from above without adequate consultation, responded with their own recommendations which would amount to a reduction in faculty overall of about 10 per cent. The ministry took into account both sets of recommendations in its final decisions. The recommendation to cut mathematics faculty across the state by 25 percent was retained; the cuts will come through attrition. The ministry decided not to shut down completely the mathematics departments in Mannheim and Konstanz, but their futures are rather uncertain. At the urging of the ministry, the University of Mannheim eliminated the *Diplom* in mathematics and instituted a new *Diplom* in mathematical computer science. The mathematics faculty at Mannheim will decline by about 35 percent, to about six full professors (and no associate professors). All of this has greatly strained the mathematics faculty and has encouraged some with offers elsewhere to leave.

The mathematics department in Konstanz retains its *Diplom* in mathematics but faces the deepest cuts of any department in the university. And it may end up in the same situation as Mannheim. According to Reinhard Racke, who has been dean of mathematics in Konstanz for the past two years, it is possible that the number of full and associate professors would decline more than 50 percent from its original number, to a total of six. The reason the decline could be so steep is a combination of the cuts mandated by the ministry and earlier negotiations about which positions would be refilled. "It's not clear to me that we can continue to survive in the next ten years," said Racke, because the department may not have the personnel to offer a sufficient number of courses for the *Diplom*. On the other hand, student numbers in the department's newly instituted program in mathematical finance are promising: forty-five students enrolled in 1999, compared with just ten in the regular mathematics program.

Similar structure commissions are now operating in two other German states, Nordrhein-Westfalen and Niedersachsen, and the state of Bavaria has also begun a less systematic but nevertheless serious examination of how to reduce spending on its universities. Karl-Heinz Hoffmann, immediate past president of the German Mathematical Society, is on the structure commission for Nordrhein-Westfalen. Hoffmann said that the commission is visiting all the universities in that state.

The entire episode in Baden-Württemberg left the mathematicians, especially those in Mannheim and Konstanz, rather shaken. "We had a terrible three years," said Racke. "It was shocking for all of us—less the fact that we had to give up positions, but more how mathematics was regarded outside and inside the university. This was really shocking."

—*A. J.*

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billionaire is powerful, the allure of the Internet seductive. And herein lies the second explanation: the public image of mathematics. In the public eye, mathematics appears less lucrative, less modern, and less dynamic than other areas. "I can imagine that in these times mathematics is not so interesting," remarked Peter Schneider of Universität Münster. "Devoting one's self to a very abstract, basic, research-oriented subject is not fashionable. The students want to make money."

Reversing the Trend

What can German mathematics departments do to reverse the decline in the numbers of *Diplom* students? According to Hoffmann, departments should offer a greater range of courses that connect mathematics to other areas, such as physics, chemistry, biology, and computer science. "We have to show that mathematics is an essential part of the natural sciences as a whole," he remarked. "We still teach mathematics as we did twenty years ago. But now there is good, strong mathematics all over science, and we have to take this into account."

In his time at the Technische Universität München (from which he is on a five-year leave), Hoffmann worked hard to invigorate the mathematics department there. The department instituted new degrees in *Technomathematik* and *Finanz- und Wirtschaftsmathematik*, which attracted many students, as well as accolades from the university administration. (The numbers in the regular mathematics *Diplom* have not, however, recovered from steep declines in the early 1990s). Among the keys in the turnaround in the department were a new, dynamic university president who supports mathematics and a wave of retirements that allowed the department to bring in a cadre of young, energetic people. Unlike in some mathematics departments, where the threat of faculty reductions has produced a siege mentality in relations between the department and the administration, the feeling at the TU München is upbeat. Said the current mathematics dean, Peter Gritzmann, "There is an atmosphere where, if you work hard and if you have ideas, there are open doors." The success at the TU München has inspired its next-door neighbor, Universität München, to follow suit and establish a new program that combines *Wirtschaftsmathematik* and actuarial science. A wave of retirements in mathematics now under way at Universität München means the mathematics department there has prospects for a renewal.

Topics like financial mathematics are a clear draw for students: The mathematics department at the Universität Konstanz, despite having just emerged from a battle over its very existence (see sidebar), instituted a program (in cooperation with the economics department) in mathematical finance and immediately drew 45 students, more than four times the current number of beginners in its regular mathematics *Diplom* program. But some worry that an overemphasis on specialization produces students who are too narrowly educated. "We should not create curricula that restrict what people can do instead of opening up new possibilities," said Wolfgang Soergel, dean of mathematics at Universität Freiburg. Rüdiger Verfürth, dean of mathematics at Ruhr-Universität Bochum, explained that his department has not considered starting programs in financial or engineering mathematics "since our experience is that the excellent job market of our students is due to their *broad* mathematical education."

Another way in which German mathematics departments are addressing the challenge of low student numbers is by strengthening their connections to local secondary schools. (The local angle is important: In Germany, secondary school students' perceptions of quality differences among universities are not pronounced, as they are in, say, the United Kingdom, where Oxford and Cambridge are perceived to be the top institutions. As a result, German students often enroll in whichever university is closest to their hometown.) To contact potential students, the Bielefeld mathematics faculty, for instance, uses a two-pronged approach. Once a year students from nearby secondary schools are brought to the mathematics department for a set of activities, including talks by former students in the department who have gone on to interesting careers. And Bielefeld mathematics faculty also travel to area schools to talk with students and teachers. "We try to give them insights into what one can do in mathematics," explained Götze. "We want to show the students something different from what they see in their usual studies of mathematics." The importance and value of such efforts are being recognized nationally: For example, the Volkswagen Foundation recently initiated a program to support such school-university linkages in mathematics.

Another approach, but one that will work only over the long term, is improving mathematics teaching in German secondary schools. As in the U.S., many in Germany believe that those intending to become mathematics teachers simply do not learn enough mathematics. There is another aspect peculiar to Germany. Prospective secondary school teachers must study two subjects and write a final paper in one of the subjects. This paper is similar to but less demanding than the *Diplomarbeit*. Those who choose mathematics as one of their subjects often write this paper in the other, presumably easier, subject. Their mathematical backgrounds are therefore not as strong as they could be, and the requirement that they study two subjects reduces the intensity of the study of both subjects. One consequence is that many students coming out of German secondary schools today lack sufficient mathematical preparation to study

any scientific and technical subject, let alone mathematics itself. "The mathematical preparation of students in schools leaves a lot to be desired," noted Samuel J. Patterson of Universität Göttingen. "We need that the faculty in universities thinks hard about how education in the schools works."

The decline in numbers of mathematics students has come at a time of new pressures on German universities, which are increasingly viewed as overly bureaucratic, inefficient, and unresponsive to change. For example, *Diplom* programs are seen as taking too long and providing an education that is too abstract and academic, leaving students to make a big adjustment when they enter the work force. Some universities are trying to make studies more flexible by initiating bachelor's degree programs, which would require only three years of study, and master's degree programs, which would require a further two years. One hope is that these new degree programs will make it easier for students from other countries where the bachelor's degree is the norm to study in Germany. Hoffmann chairs a national committee to provide accreditation guidelines for these new degree programs.

Such structural changes are hard to make. What is even harder is tackling the problem of the public image of mathematics, an important factor in the decline in numbers of mathematics students in Germany—and elsewhere. Mathematicians everywhere share this problem. It is an international phenomenon.

—Allyn Jackson

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